PDFs and TMDs

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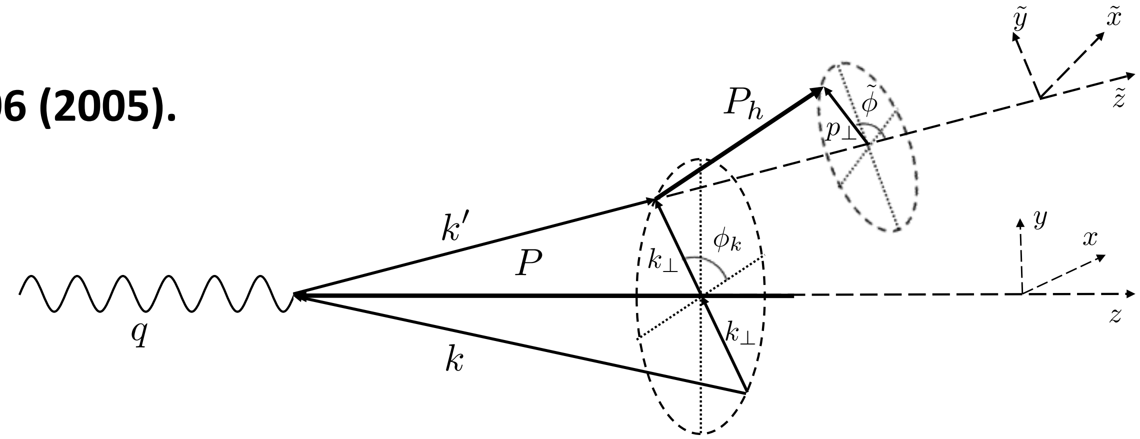
Outline

- Fully differential MC
  - Single hadron
  - Multi-hadron production model
- Results
- Summary and outlook

Model for fully differential SIDIS dedicated MC

Anselmino: PRD 71, 074006 (2005).



Quark intrinsic motion with Torino model: $M_p \neq 0 \quad x_{LC} = k^- / P^-$

Quark inside the proton have the momentum:

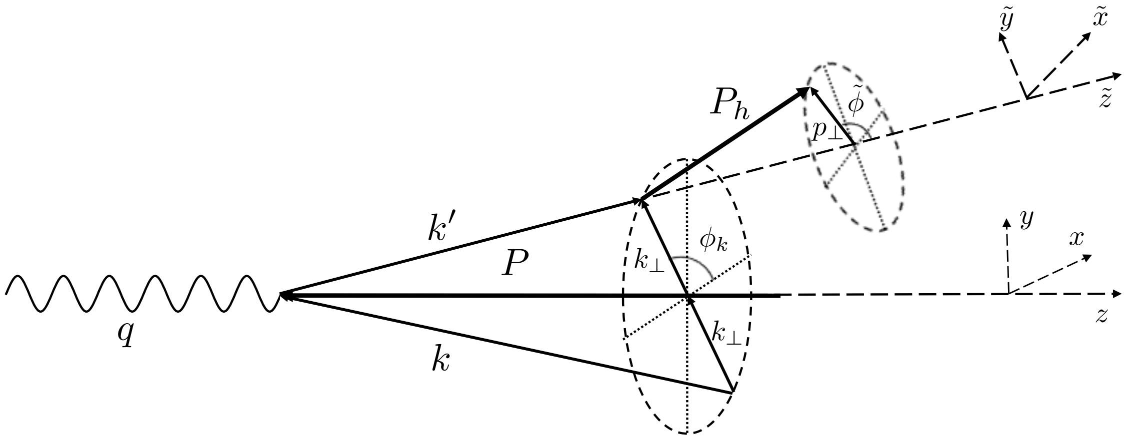
$$k = \left(x_{LC} P' + \frac{k_\perp^2}{4 x_{LC} P'}, \mathbf{k}_\perp, -x_{LC} P' + \frac{k_\perp^2}{4 x_{LC} P'} \right)$$

$$x_{LC} = \frac{x}{x_N} \left(1 + \sqrt{1 + \frac{4 k_\perp^2}{Q^2}} \right), \quad x_N = 1 + \sqrt{1 + \frac{4 M_p^2 x^2}{Q^2}},$$

Where $P' = 0.5(E_p + |P_{pz}|)$ is the proton energy with non zero proton mass.

Thanks to: M. Anselmino, U. D'Alesio, S. Melis, A. Kotzinian

Fragmentation



Scattered quark 4 momentum calculated: $k' = k + q$

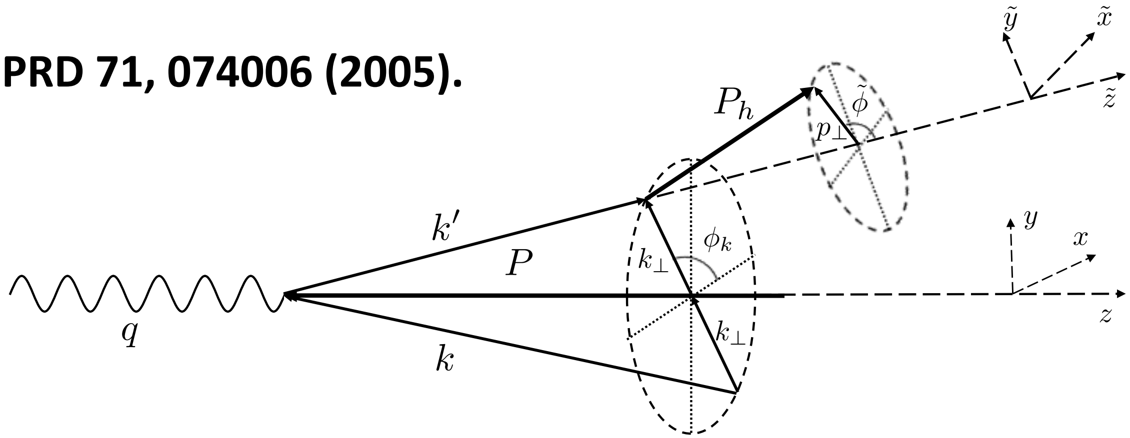
Final hadron generated with the momentum:

$$P_{\tilde{x},h} = p_\perp \cos(\tilde{\phi}) \qquad P_{\tilde{y},h} = p_\perp \sin(\tilde{\phi}) \qquad P_{\tilde{z},h} = z_{LC} E_{k'} - \frac{p_\perp^2 + M_h^2}{4 z_{LC} E_{k'}}$$

To account and understand all the assumptions, integrations, correlations and more, fully differential SIDIS cross-section should be studied.

Cahn effect in MC

Anselmino: PRD 71, 074006 (2005).



$$\frac{d\sigma}{dxdydzd^2\mathbf{p}_\perp d^2\mathbf{k}_\perp} = K(x,y)J(x,Q^2,k_\perp)\sum_q f_{1,q}(x,k_\perp)D_{1,q}(z,p_\perp)\frac{\hat{s}^2+\hat{u}^2}{Q^4}$$

$$\hat{s} = (l+k)^2$$

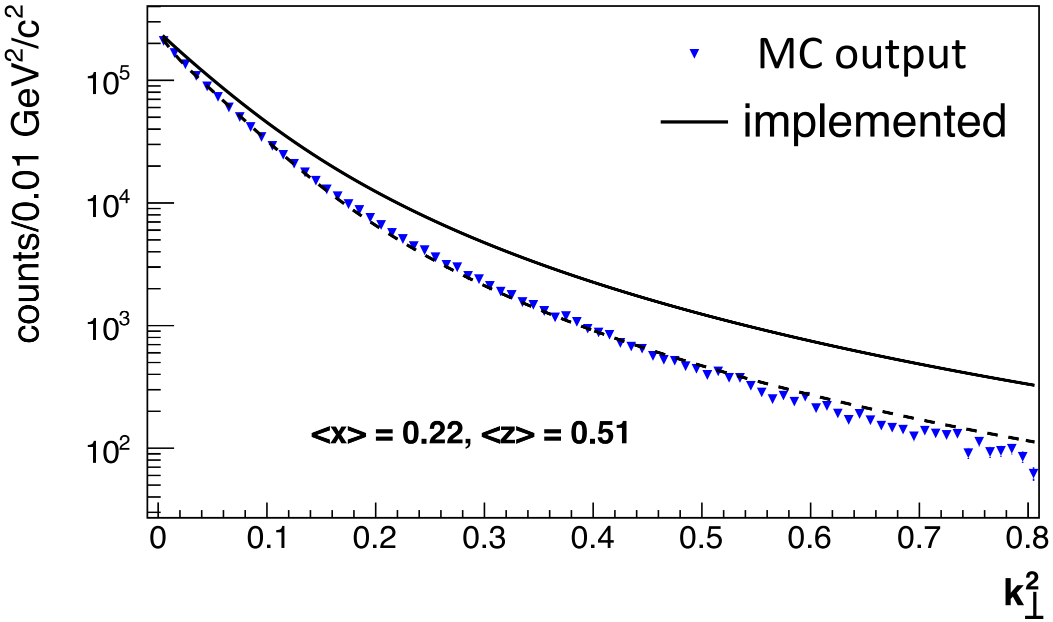
$$\hat{u} = (k-l')^2$$

Cahn effect implemented according to Anselmino: PRD 71, 074006 (2005).

Constrain

- Quark transverse component of the momenta is smaller than LC component.

$\langle k_\perp^2 \rangle$ -depends on x and $\langle p_\perp^2 \rangle$ -depends on z



$$f(k_\perp) = \left[1. + 20.82k_\perp^2 + 126.7k_\perp^4 + 1285k_\perp^6\right]^{-1}$$

Requirements for MC

Collins,Rogers,Staśto:PRD77,085009,2009

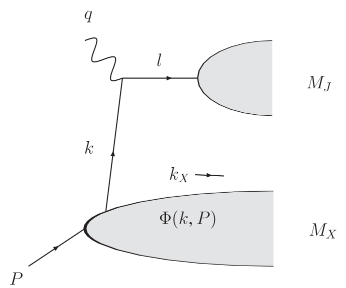
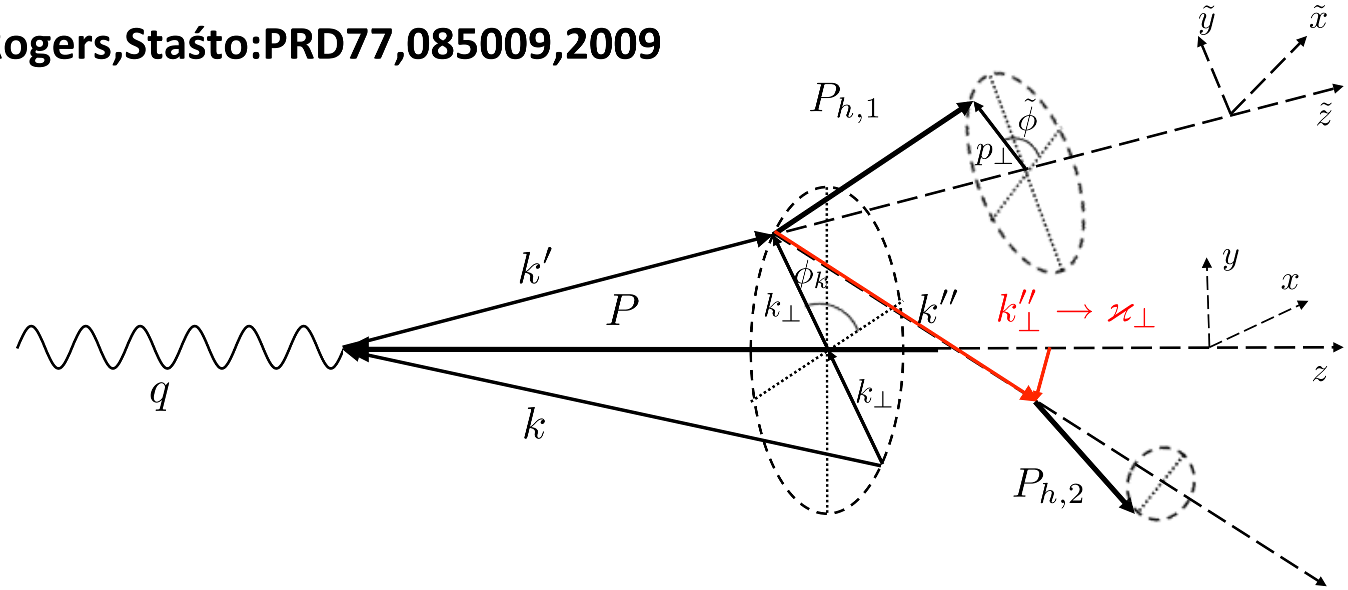


FIG. 2. The amplitude for $\gamma^* p$ scattering into two jets with fixed masses.

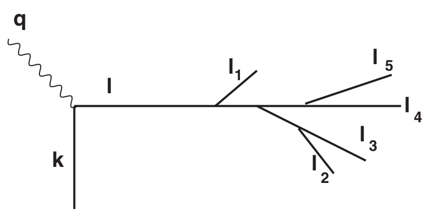
- The kinematics of the initial and final states must be kept exact.
- The sums over physical final states must be kept explicit.
- To avoid making kinematical approximations in the initial and final states, the factors need to be function of all components of parton four-momentum.
- The hard-scattering matrix element should appear as on-shell parton matrix element in the final factorization formula.

Model for multi-hadron production

Collins,Rogers,Staśto:PRD77,085009,2009



PHYSICAL REVIEW D **77,** 085009 (2008)

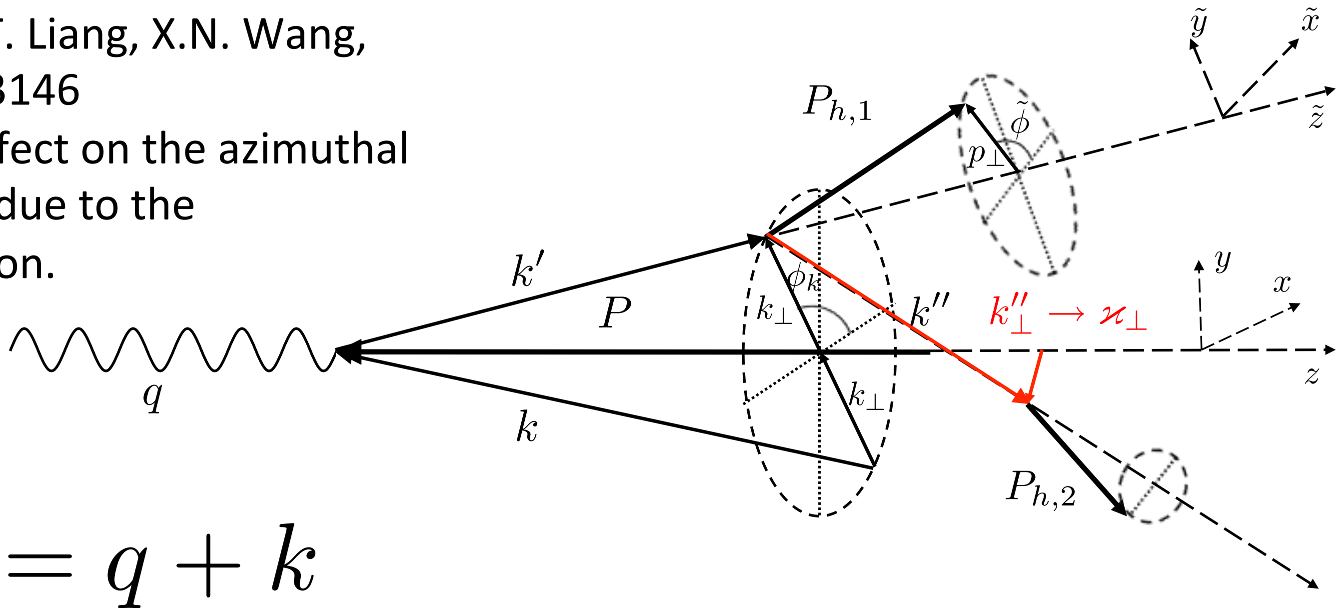


$$k' = q + k$$
$$k'' = k' - P_{h,1}$$

Four momenta conservation at each vertex.

Model for multi-hadron production

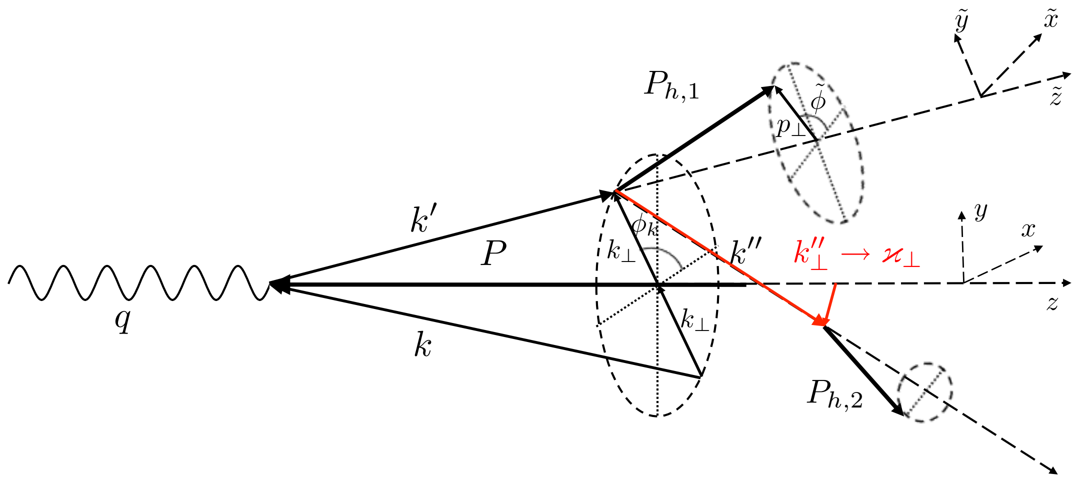
J.H. Gao, Z.T. Liang, X.N. Wang, arXiv:1001.3146
Smearing effect on the azimuthal asymmetry due to the fragmentation.



$$k' = q + k$$
$$k'' = k' - P_{h,1}$$
$$k''' = k'' - P_{h,2}$$

Change of notation for convenience $k''_\perp \to \varkappa_\perp$

Inputs for MC



Collinear FFs: DSS or HKNS

Gaussian with:

$$\langle p_\perp^2 \rangle_q = C_q \times z \cdot (1-z)^{0.9}$$

Collinear PDFs: MSTW
Gaussian with:

$$\langle k_\perp^2 \rangle_q = D_q \times (0.01 + x)^{0.9} \cdot (1-x)^{6.}$$

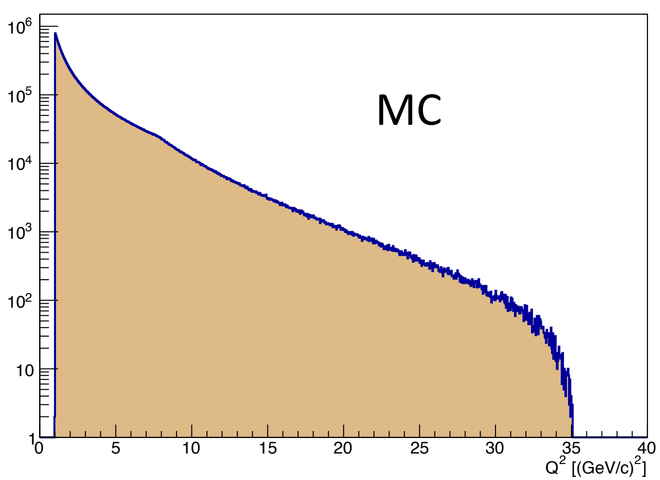
$$k' = q + k$$

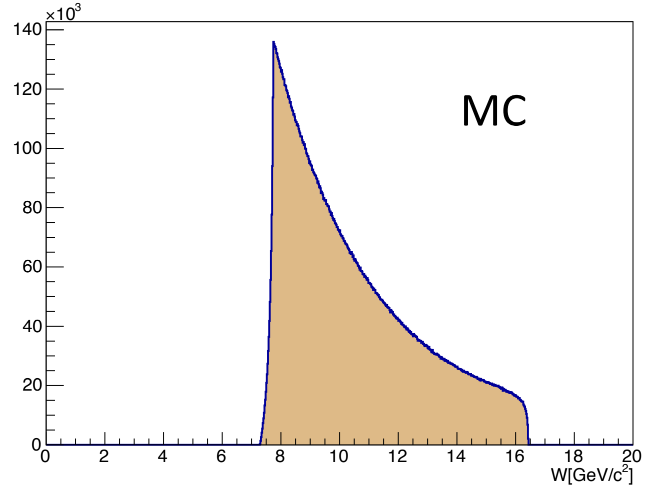
$$k'' = k' - P_{h,1}$$

$$k''' = k'' - P_{h,2}$$

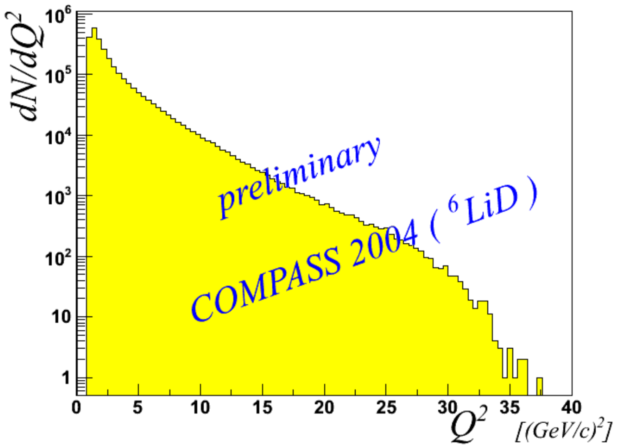
Unfavored FF and $k''_\perp \to \varkappa_\perp$ is being calculated from four-momenta conservation.

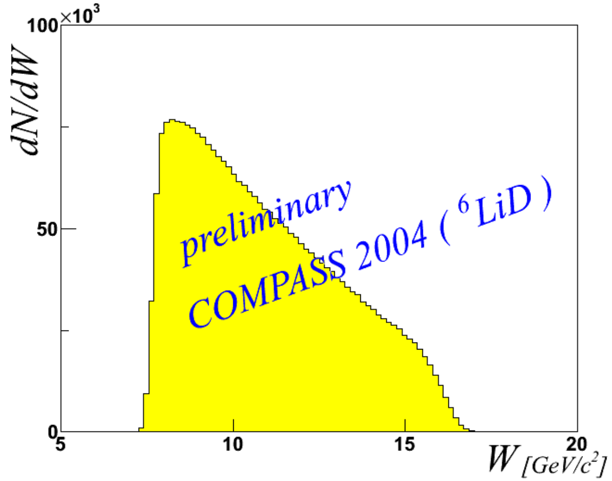
Outcome of MC at 160 GeV



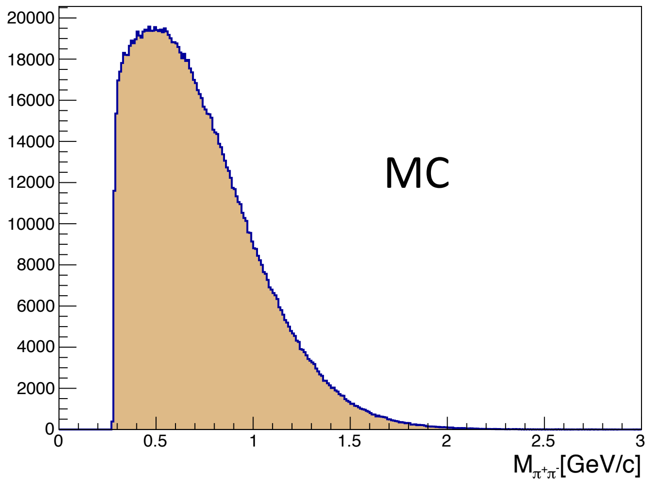


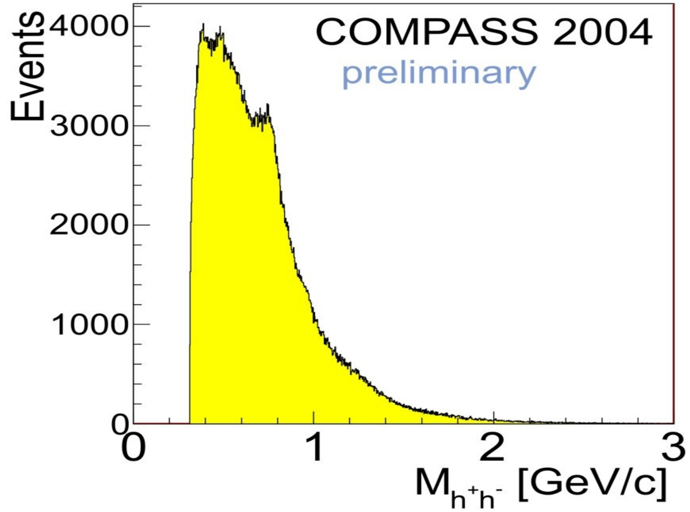
Nice agreement (COMPASS acceptance is not applied to MC)





Outcome of MC at 160 GeV

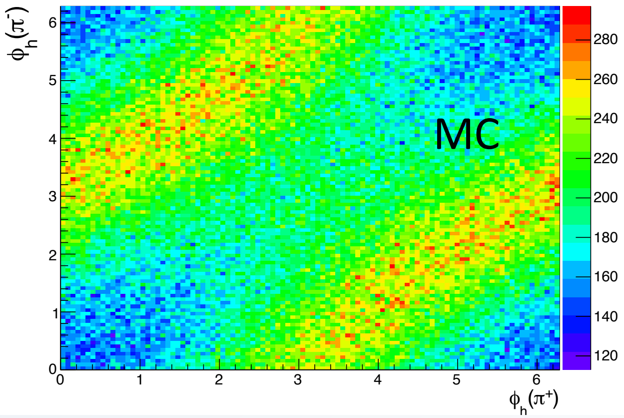


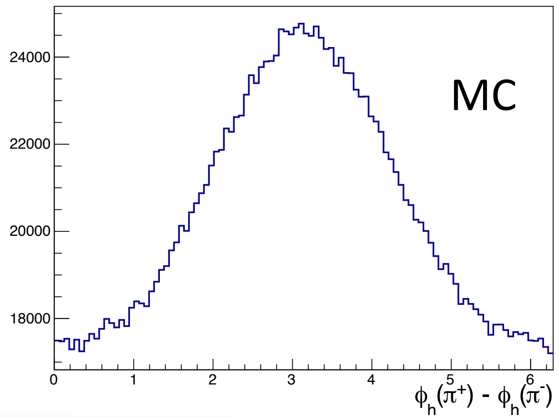


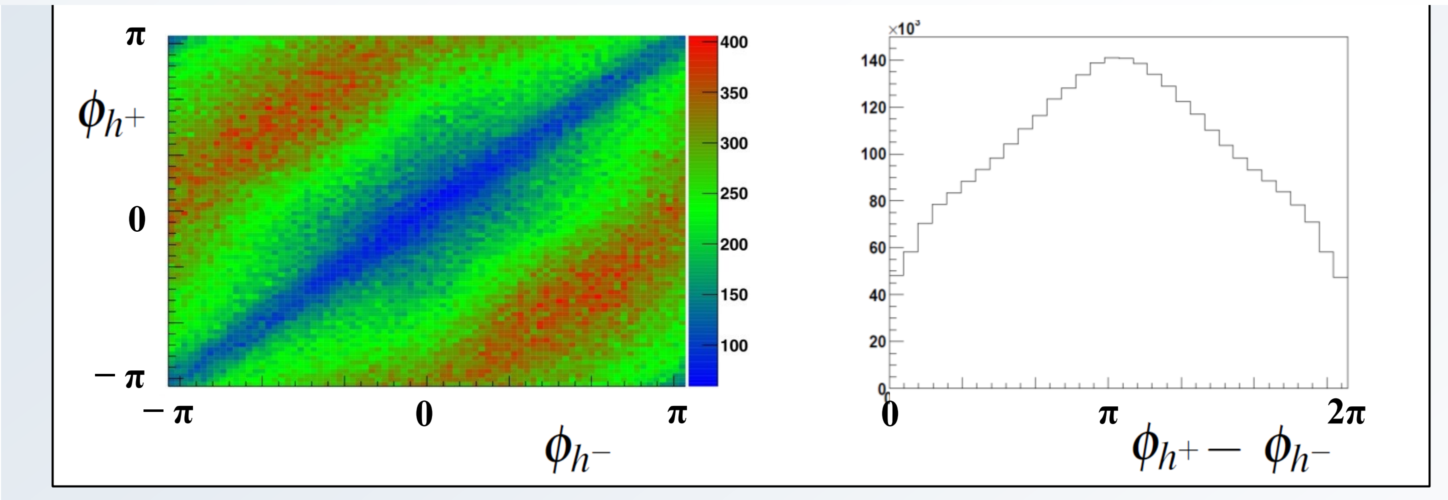
From A.Martin presentation at Como.

Vector meson production in MC is not included yet!

Outcome of MC at 160 GeV



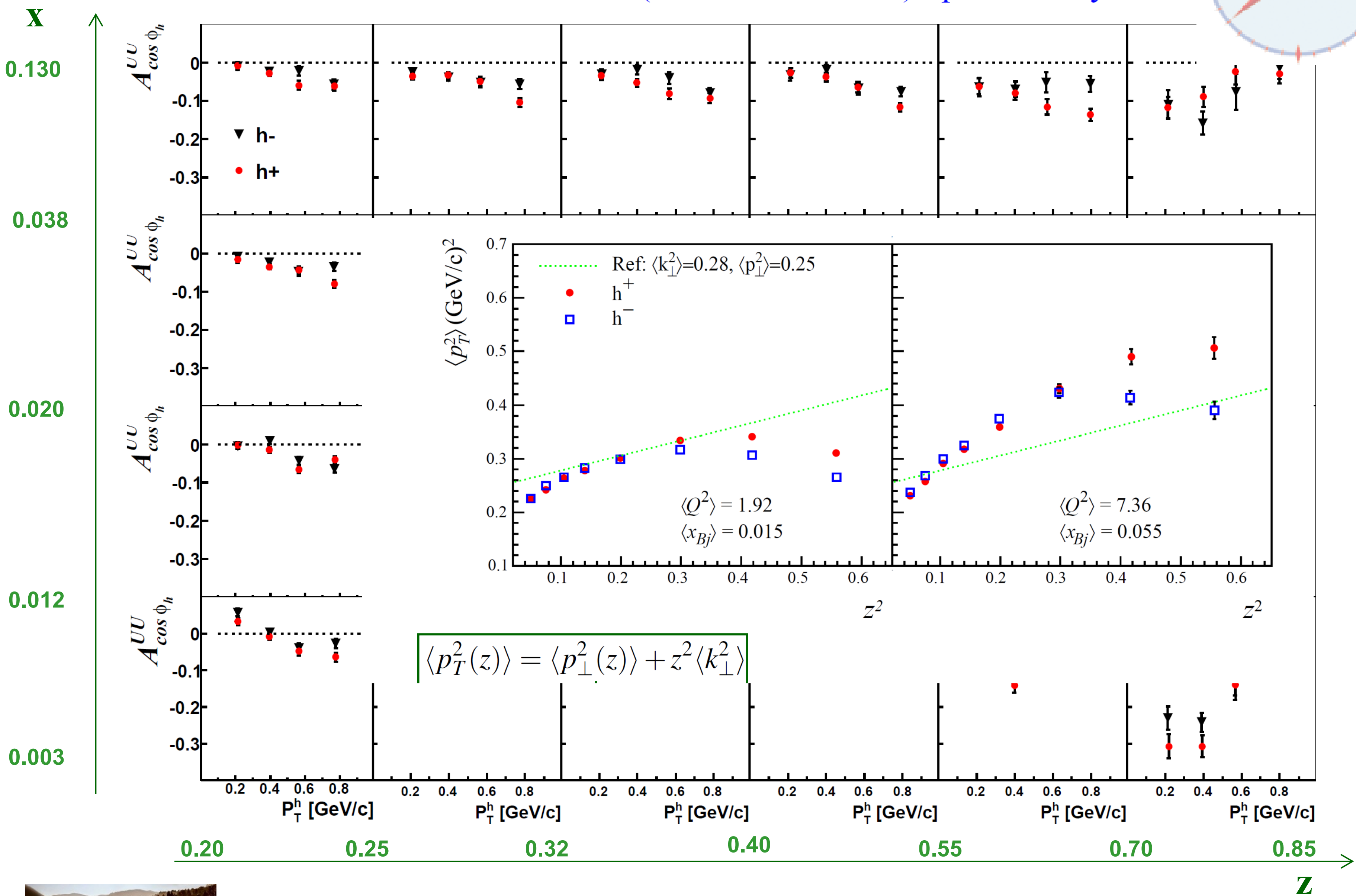




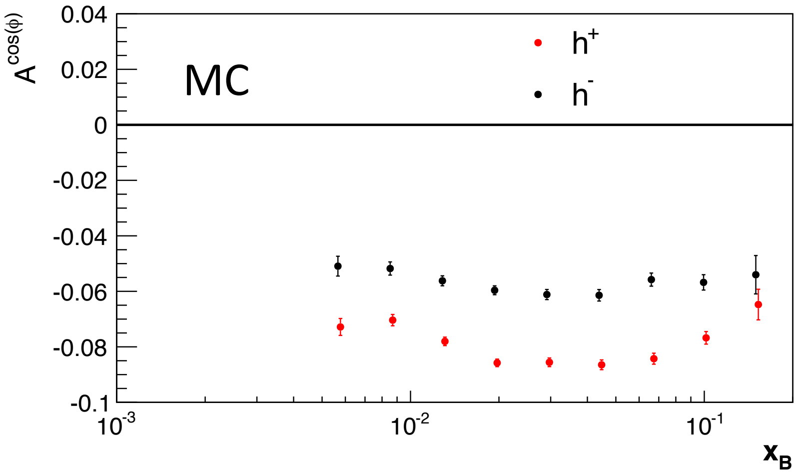
Reasonable agreement even w/o COMPASS acceptance.

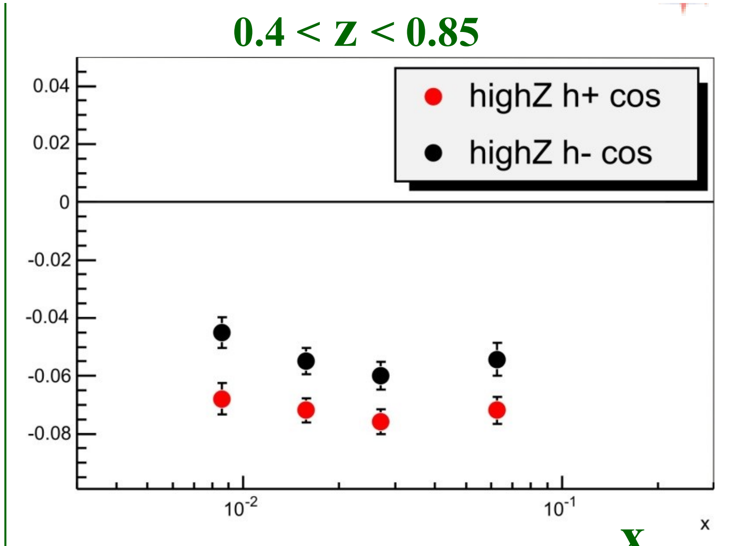
azimuthal asymmetries - cos ϕ

COMPASS ^{6}LiD (25% of 2004 data) preliminary



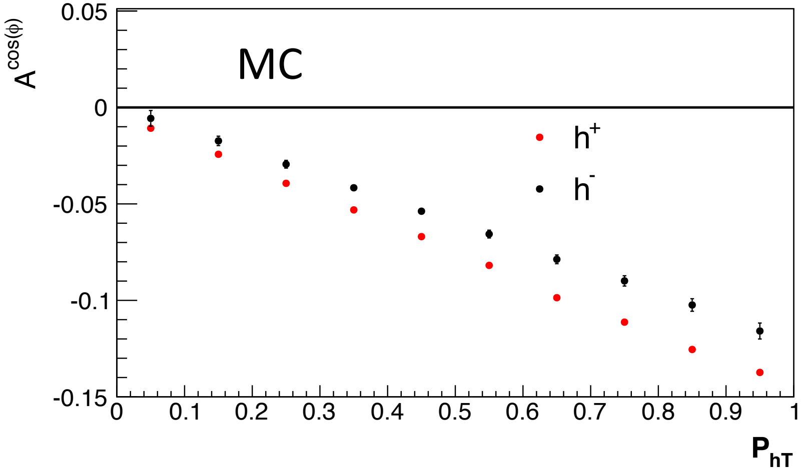
Cahn effect from MC and $A^{\cos\phi}$ from Data

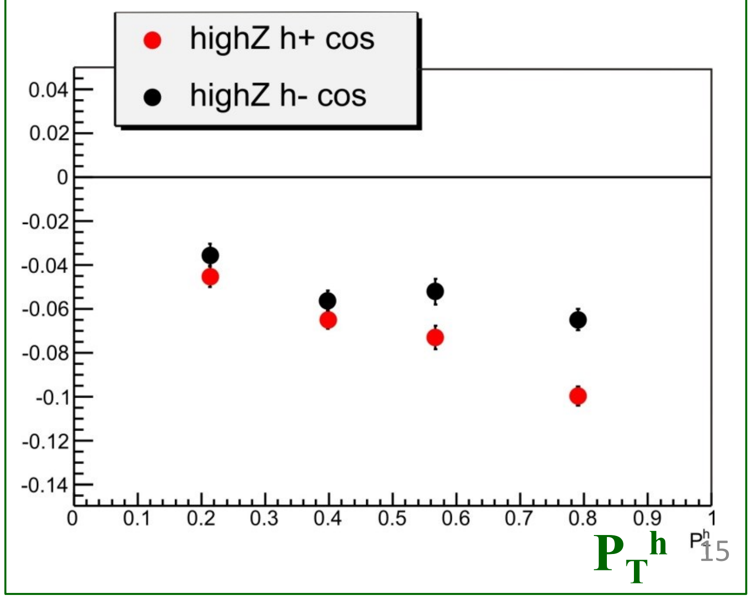




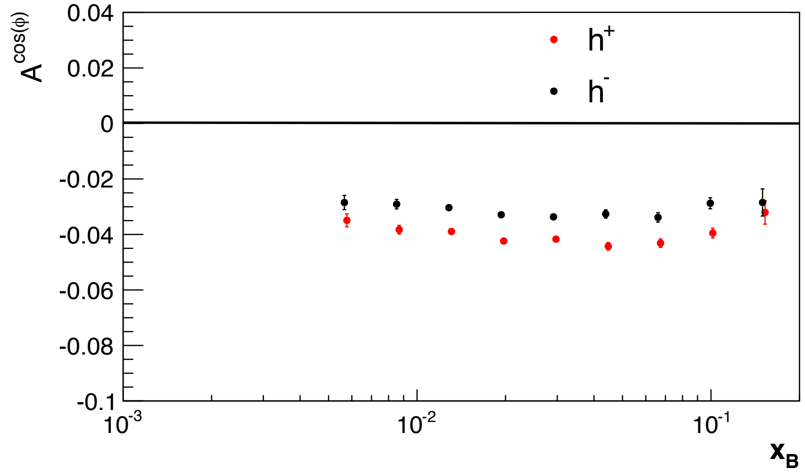
Reasonable agreement at high z

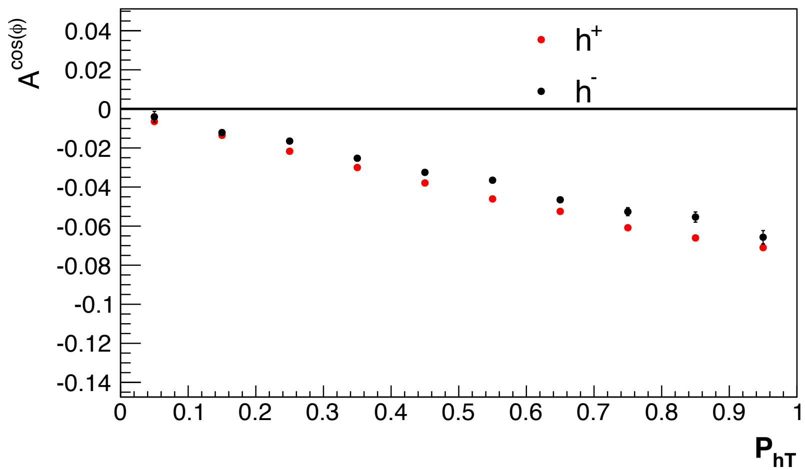
A. Martin, Como, June, 2013



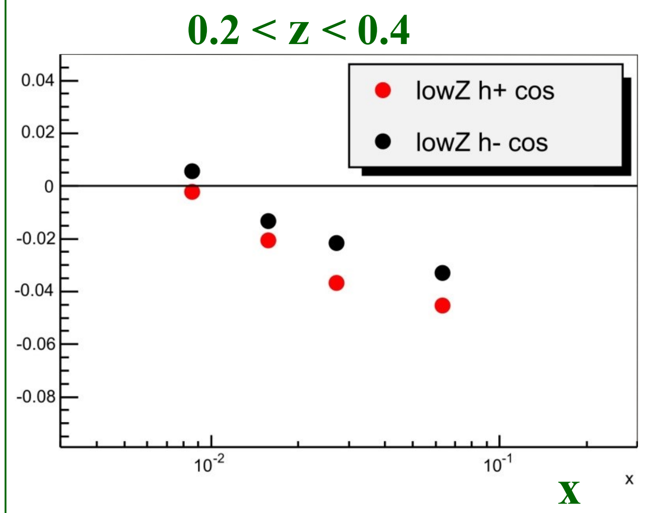


Cahn effect from MC and $A^{\cos\phi}$ from Data

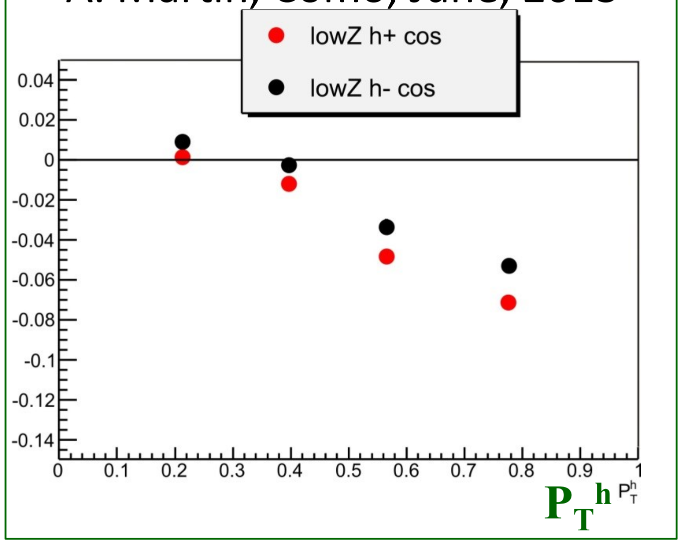




With current model I can not describe low z

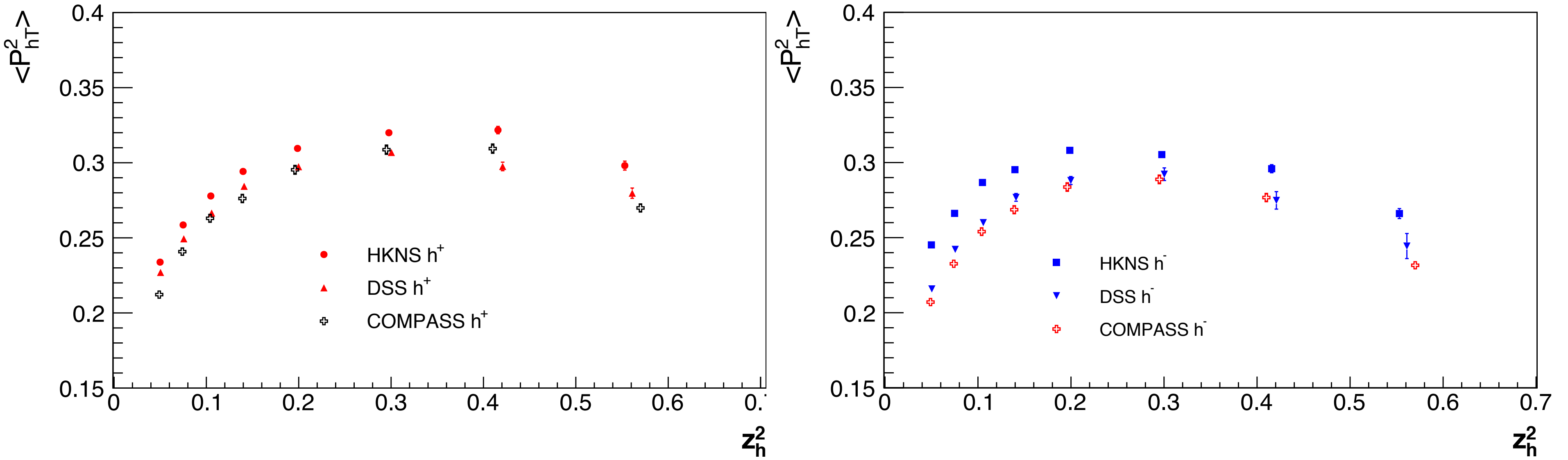


A. Martin, Como, June, 2013



MC vs COMPASS average transverse widths

$$\langle x_B \rangle = 0.0213, \langle Q^2 \rangle = 1.23(GeV/c)^2$$



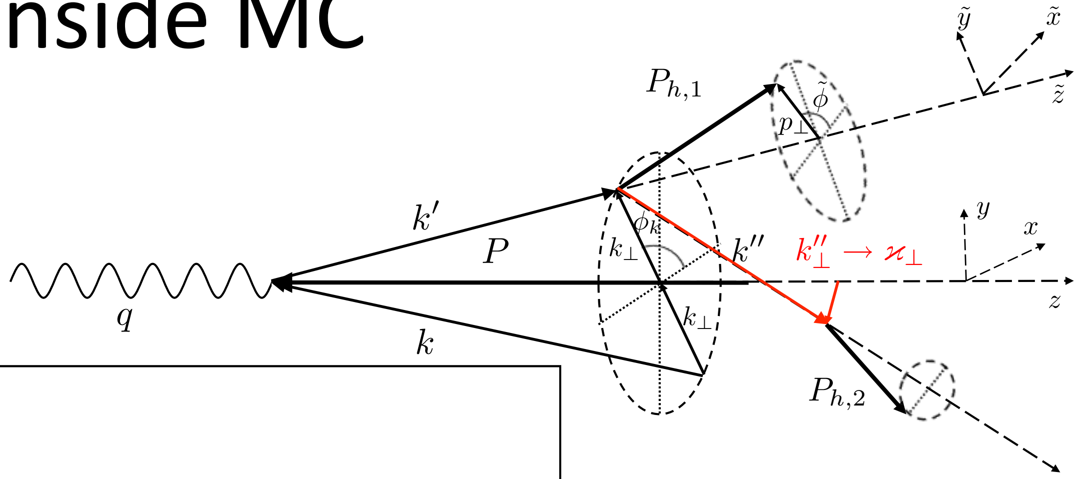
$$\langle p_\perp^2 \rangle_q = C_q \times z \cdot (1 - z)^{0.9}$$

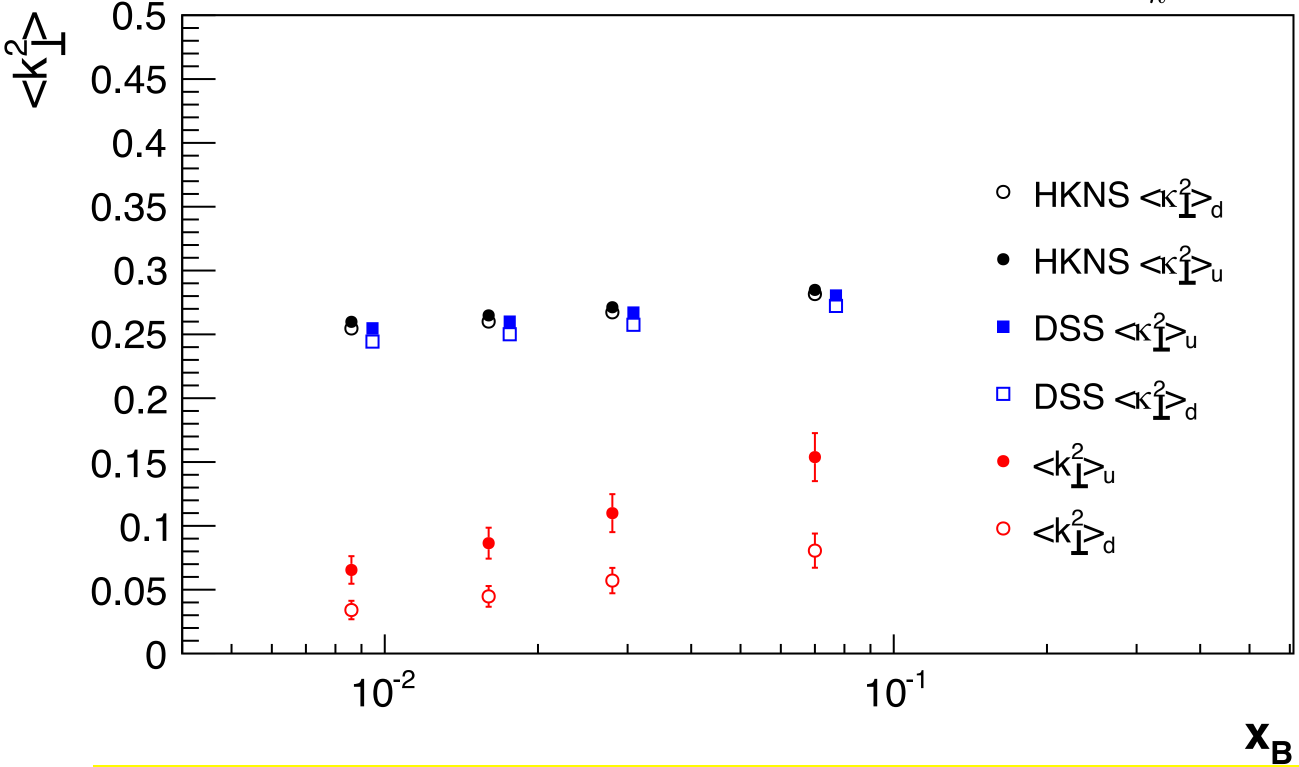
For fixed input transverse widths in FF and DF:
change of the collinear FFs effects detected hadrons transverse widths.

Inside MC

J-H. Gao, Z-T. Liang, X-N. Wang, arXiv: 1001.3146

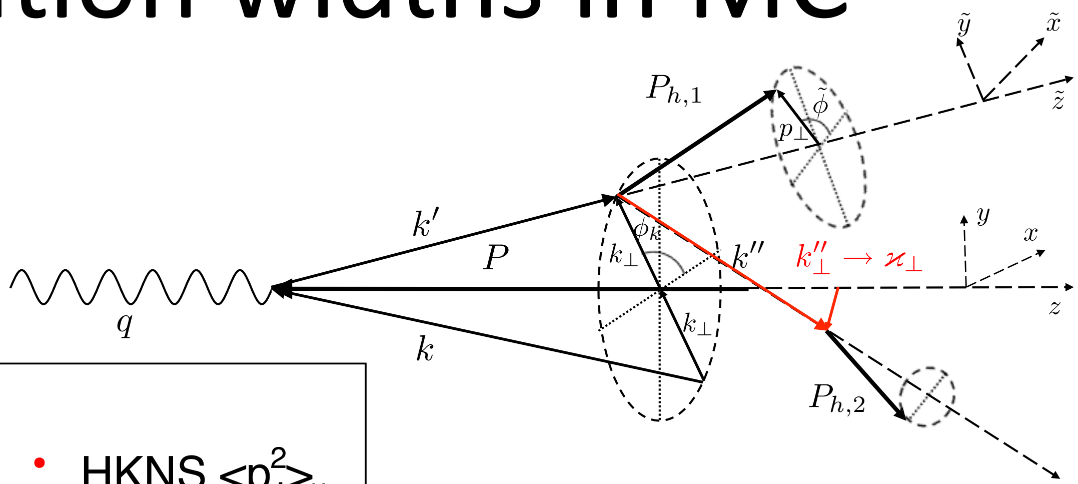
Smearing effect on the azimuthal asymmetry due to the fragmentation.

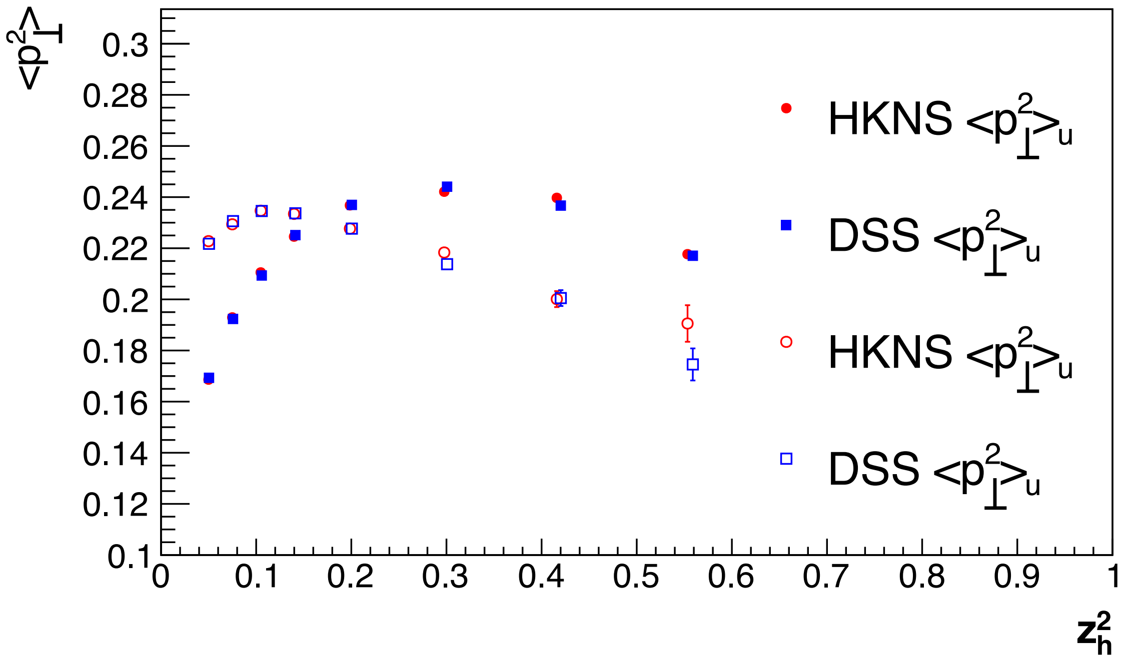




Quarks Intrinsic transfer momenta "smearing" is in the order of factor 2- 5 times.

Fragmentation widths in MC

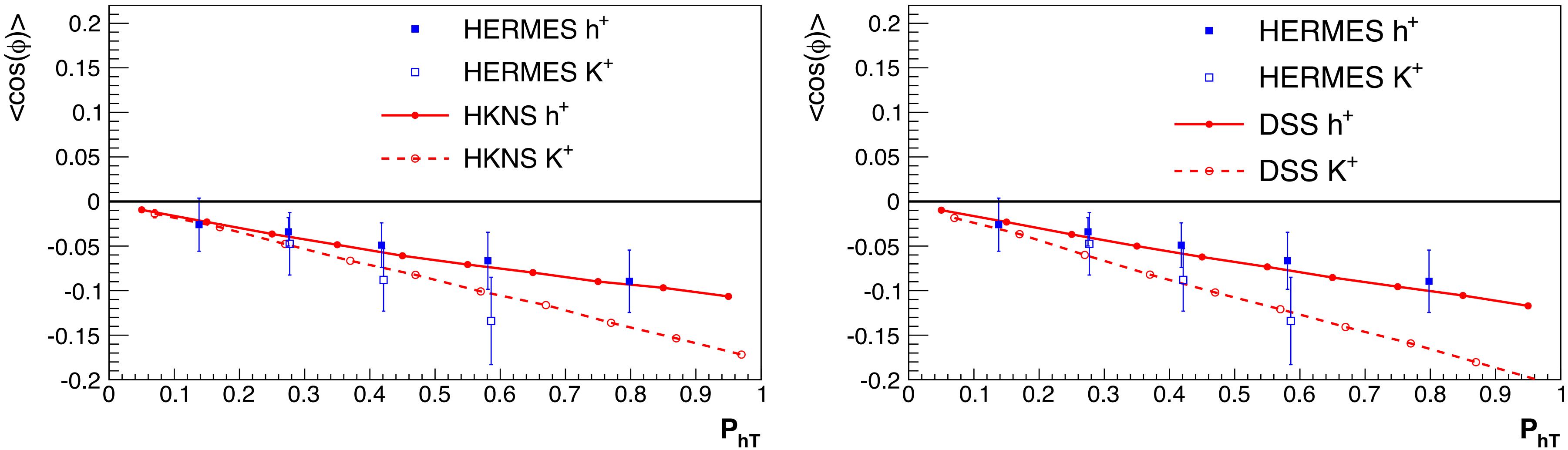




J-H. Gao, Z-T. Liang, X-N. Wang, arXiv:1001.3146
Smearing effect on the azimuthal asymmetry due to the fragmentation.

Transverse widths from secondary fragmentations are wider from favored FF widths only at small z.

Cahn effect from MC and <cosϕ> from HERMES Data



For the same fixed input widths the outcome of MC depends on FFs.

Summary

- SIDIS data sensitive to quark “initial” intrinsic transverse momenta only at high z. (smearing due to the fragmentation dominates at low z).
- TMD fits should be done together with collinear FFs.

Thank you!

Support

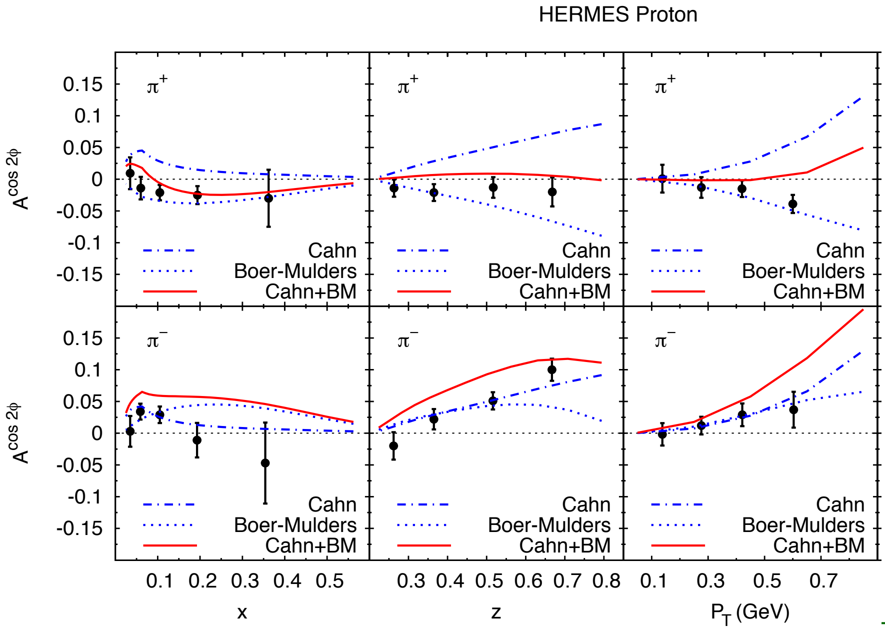
Smearing effect due to the Fragmentation

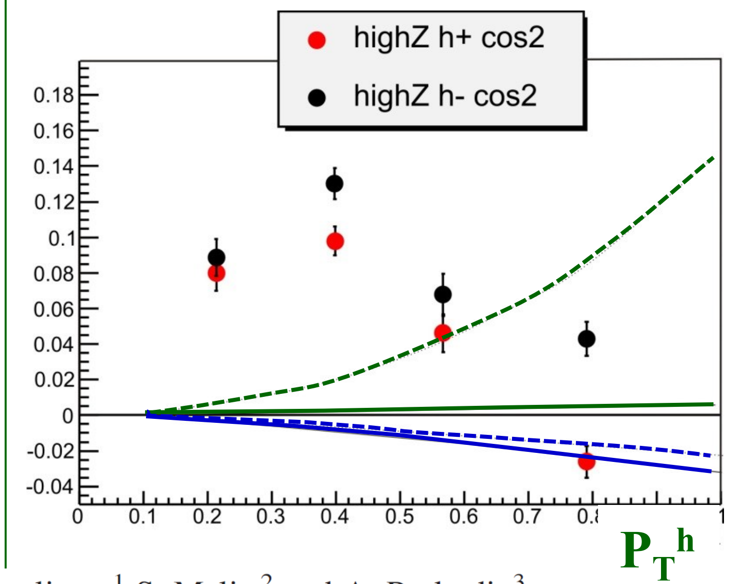
We compare the above results with those obtained without fragmentation, Eqs. (48) and (49), and see that we have a clear smearing effect on the azimuthal asymmetry in both $e^- N$ and $e^- A$-scatterings. The smearing factors are given by,

$$\frac{\langle \cos\phi_h \rangle_{eN}}{\langle \cos\phi \rangle_{eN}}\Big|_{|\vec{p}_{h\perp}|=z|\vec{k}_\perp|} = \frac{\beta z^2}{\beta z^2 + \alpha_F}, \tag{58}$$

$$\frac{\langle \cos\phi_h \rangle_{eA}}{\langle \cos\phi \rangle_{eA}}\Big|_{|\vec{p}_{h\perp}|=z|\vec{k}_\perp|} = \frac{(\beta + \Delta_{2F}) z^2}{(\beta + \Delta_{2F}) z^2 + \alpha_F}. \tag{59}$$

Cos 2 ϕ_h



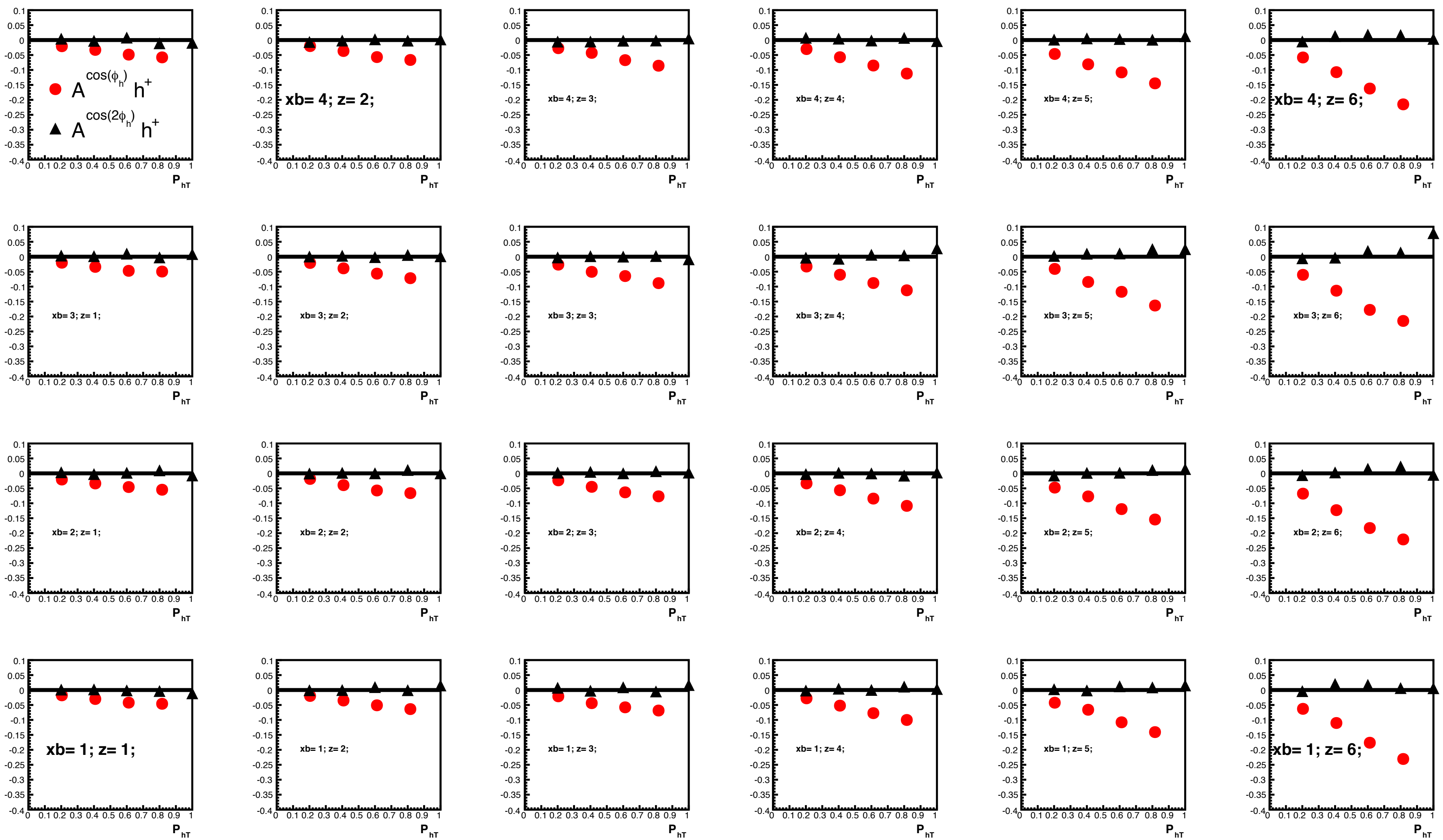


M. Boglione,[1] S. Melis,[2] and A. Prokudin[3]

Anna Martin

Current model calculations are not support by experimental measurements.

Cahn from MC



Cos $2\phi_h$ from Cahn for positive hadrons is consistent with zero